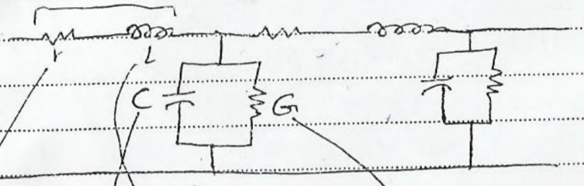
Subject: ....

Transmission line

- Overhead T.L
- Underground Cable

T.L Parameters :-

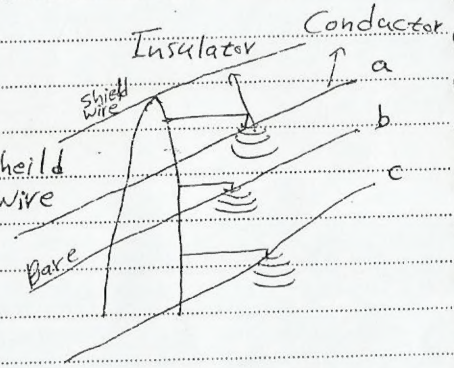
$Z \equiv$ Series impedance

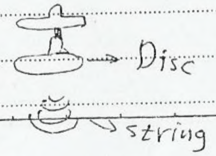


- Resistance
- Inductance
- Capacitance
- Conductance

Components of T.L :-

- Conductor
  - Copper
    - higher Conductivity
  - Aluminium
    - Low Cost
    - Lighter Wieght
    - It's Supply not Limited
- Insulator
- Supporting Structure
- Sheild Wire





2

فودهامة قصيرها

$$\lambda_i = 2\times10^{-7}\left(L_i \, Lin\left[\frac{1}{r'}\right] + \sum_{j=1}^{n} L_j \, Lin\left[\frac{1}{D_{ij}}\right]\right)$$

$a^2 + a + 1 = 0$ $I_B = a^2 I_a$ $I_c = I_a a$

$a^2 = \angle 240$ $a = \angle 120$

1

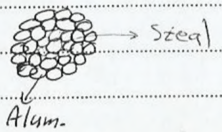
Phase — Single Conductor
Bundle حزمة

types of Aluminium
aluminum Conductor Steel Supported (ACSS) مقوى → Use for higer temperature >150c
ACSR ≡ Alum. Condutore Steel Reinforced (most common)

AAC ≡ All Alum. Cond. (AAAC «All Aluminum-Alloy Conductor»)

ACAR ≡ Alum. Cond. Alloy سبيكة Reinforced
Aluminum-clad Steel Conductor (Alumoweld).

Ex
ACSR (24 / 7)
24 → Alum.
7 → Steal



* T.L is based design on optimization اختيار of electrical, mechanical, enviromental بيئية and economic اقتصادية factors.

eletrical factors:

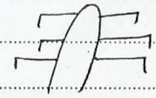
[1] Voltage level — كل ما تزيد الجهد تنقل power أكثر
[2] Cond. Capacity — و يستخدم في المسافات الطويلة
[3] Strands
[4] Bandle

Subject: .... / [2] /

Conductor
- Solid
- Strands
  - Easier to handle سهل التناول
  - Easier to manufacture سهل التصنيع
  - More flexible أكثر مرونة

Insulator
- زجاج Glass
- Porcelgien / Porcelain
- Rubber مطاط

« شكل البرج » Supporting Structure →



Shield Wire
- Steel
- Aluminum
→ Lightning الصاعقة

لحماية المكونات من الصاعقة
و يستخدم أيضاً في الاتصالات

4 3

Conductivity $\leftarrow \sigma = \frac{1}{\rho} \rightarrow$ resistivity

Symbol	SI Units	English Units
ρ	$\Omega \cdot m$	Ω Cmil/ft
L	m	ft
A	m^2	Cmil
$R_{dc} = \frac{\rho L}{A}$	Ω	Ω

mil $\times$ mile (mi)

1 inch = 1000 mil

1mile = 63.36×10^6 mil

1mile = 63360 inch

1mile = 5280 ft

1mile = 1760 yards

1mile = 1609 meter

1 yards = 3 ft

القطر

d ≡ diameter

1 ft = 12 inch

A (Cmil) = d^2

Circular mils

1 inch = 2.54 cm

$A = d^2$ cmil $= \frac{\pi}{4} d^2$ Sq mil

1000D = 1d

الظاهرة القشرية

frequency ~~(Skine effect)~~ (Skin effect)

$R_{ac} > R_{dc}$

أكبر من

Current density at the conductor Surface $>$
Current density at the Center

$f \uparrow \Leftrightarrow$ Skin effect $\uparrow$

$R_{ac} = \left(\begin{matrix}\text{factor} \\ \text{Sink effect}\end{matrix}\right) \cdot \left(R_{dc}\right)$

Subject:

1 mil = 2.54×10^{-8} Km

Resistance :-

$R_{dc} = \frac{\rho L}{A}$

Resistivity, length, resistance, Crossection Area مساحة المقطع

$\rho_T \equiv$ Conductor resistivity at temperture (T)

$L \equiv$ Conductor length

$A \equiv$ Conductor Cross-Sectional Area

$R_{ac} = \frac{P_{loss}}{|I|^2}$ $[\Omega]$

$R_{ac} > R_{dc}$

Factors :

1. Material
2. length
3. ~~Tempture~~ Temprature
4. CSA (Cross Section Area)
5. Spiralling (عدد اللفات) (1 → 2) % of length $\boxed{(1.01)L}$ 2%

$R_2 = R_1 \frac{(T_2 + T_0)}{(T_1 + T)}$

Temp. Coefficient Bundle

$\rho_{T_2} = \rho_{T_1} \left(\frac{T_2 + T}{T_1 + T}\right)$ $T \rightarrow [°C]$

1mile = 63.36×10^6 mil = 63360 inch = 5280 Ft = 1609 m

mile → mi

Subject:....................... 4 / /

Ex 8

A 4/0 Copper Conductor With 12 Strands. Strand diameter is 0.1328 in. for this conductor.

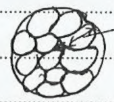
a) Verify The total copper C.S.A of 211,600 cmil

b) " The dc resistance at 50°C of Ω/mi. Assume a 2% increase in resistance due to Spiralling ; $\rho_{20°C} = 10.66\ \Omega\ \text{cmil/ft}$, $T = 241.5°C$

c) From Table A3 determine The percent increa[se] in resistance at 60 Hz Versus dc

Solutoins

a)



dia 0.1328 in

$d = 0.1328 * 1000 = 132.8\ \text{mil}$

C.S.A of 1 Strand $= d^2 = (132.8)^2 = 17635.84$ cmil

C.S.A of the conductor $= 12 * 17635.84$

$= 211630.08$ cmil

≈ 211600 cmil

b) $R_2 = R_1 \left(\frac{(T_2 + T)}{(T_1 + T)}\right)$

$\rho_2 = \rho_1 \left(\frac{(T_2 + T)}{(T_1 + T)}\right)$

$\rho_{50} = 10.66 \left(\frac{(50 + 241.5)}{(20 + 241.5)}\right)$

$\rho_{50} = 11.8829\ \Omega\ \text{cmil/ft}$

$R_{50} = \rho_{50} \frac{L}{A} = \frac{11.88 * 5280 * 1.02}{211600} = 0.3024\ \Omega/\text{mi}$

c)

@ 60 Hz, 25°C: $\frac{R_{ac}}{R_{dc}} = \frac{0.278}{0.276} = 1.007$ $\boxed{0.7\%}$

@ 60 Hz, 50°C: $\frac{R_{ac}}{R_{dc}} = \frac{0.303}{0.302} = 1.003$ $\boxed{0.3\%}$

$100 + \frac{10 \times 100}{10}$

$R = \frac{11.88}{211600} = 5.614 \times 10^{-5}\ \frac{\Omega}{Ft}$

$= 5.614 \times 10^{-5} \times 5280$

$= 0.296\ \Omega/\text{mil}$

وعند إضافة تأثير spiralling تصبح ((%2))

$0.296 + 0.296 \times \frac{2}{100} = 0.302$

8 7

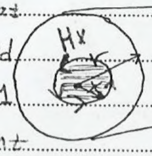
H ≡ Magnetic field intensity
B ≡ Magnetic flux density

$L = L_{int} + L_{ext}$
(internal) (external)

(Constant Value) ← $L_{int} = \frac{1}{2} \times 10^{-7}$ H/m

$L_{ext} = 2 \times 10^{-7} \ln\left(\frac{D_2}{D_1}\right)$

assume that the Conductor:
1) is sufficiently long that end effects are neglected
2) is nonmagnetic $\mu_r = 1$
3) has a uniform current density (Skin effect is neglected)



$\oint H_x \, dl = I_x$

$H_x L = N I_x$; $N = 1$

$H_x (2\pi X) = I_x$

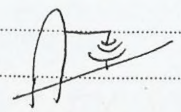
① ← $\boxed{H_x = \frac{I_x}{2\pi X}}$ [A/m]

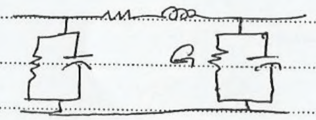
total current ← $\frac{I}{\pi r^2} = \frac{I_x}{\pi X^2}$ When Uniform

② ← $\boxed{I_x = \frac{X^2}{r^2} I}$ When uniform current distribution within the conductor

① & ② ← $\boxed{H_x = \frac{X^2 I}{2\pi X r^2} = \frac{X}{2\pi r^2} I}$

Conductance:





For OHTL There are power loss due to
i) leakage current at The insulators
ii) Corona: Occurs When high Value of electric field Strength ~~at~~ at a conductor Surface causes the air to become electrically ionized and to Conduct. ⇒ (Corona losses)
The real power loss due to corona, called Corona loss

Inductance: ((Solid Cylindrical Conductor))

$L = N \frac{d\phi}{dI} = \frac{N\phi}{I} = \frac{\lambda}{I}$ → flux linkages

$\boxed{\text{Lenz's law}}$ → for review → $L = N \frac{d\phi}{di_L}$ [H]

$N = 1$

$e_L = L \frac{di_L}{dt}$ [V]

$L = \frac{\lambda}{I}$
Inductance

$\mu \equiv$ Permeability

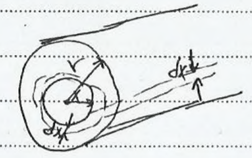
Subject:......التفاضلية $\qquad \mu_0 \mu_r \rightarrow \mu_r = 1$ $\quad$ / / $\quad$ 6

~~nonmagnatic~~

$$B_x = \mu H_x$$

$$\boxed{B_x = \mu_0 H_x = \frac{\mu_0 I X}{2\pi r^2}} \quad [Wb/m^2] \; [Tesla]$$

$$\emptyset = B A \quad ; A = dx . 1$$



Differential $\emptyset$ for a small region of dx for 1m long

$$\boxed{d\emptyset = B_x \, dx} \quad [Wb/m]$$

$$\boxed{d\emptyset = \frac{\mu_0 I X \, dx}{2\pi r^2}}$$

$$d\lambda_{int} = \frac{\pi x^2}{\pi r^2} \, d\emptyset$$

$$d\lambda = \frac{X^2}{r^2} \frac{\mu_0 I X}{2\pi r^2} \, dx$$

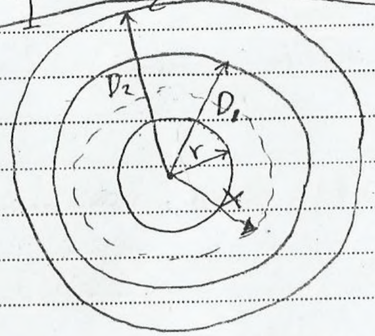
$$d\lambda = \frac{X^3 \mu_0 I}{2\pi r^4} \, dx$$

$$\lambda_{int} = \int_0^r \frac{X^3 \mu_0 I}{2\pi r^4} \, dx$$

λ internal

$$\lambda_{int} = \frac{\mu_0 I X^4}{8\pi r^4} \Big|_0^r = \frac{1}{2} * 10^{-7} I \quad [Wb\text{-}t/m]$$

$$\boxed{L_{int} = \frac{\lambda_{int}}{I} = \frac{1}{2} \times 10^{-7} \; H/m}$$



$$B_x = \frac{\mu_0 I x}{2\pi x} = \frac{\mu_0 I}{2\pi X} \quad ; I = I_x$$

$$\emptyset_x = B_x A$$

$$d\lambda = d\emptyset$$

$$d\lambda = \frac{\mu_0 I}{2\pi X} dx$$

$$\lambda_{ext} = \int_{D_1}^{D_2} \frac{\mu_0 I}{2\pi X} dx$$

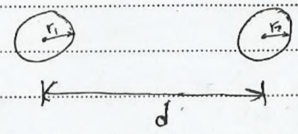
$$\lambda_{ext} = \frac{\mu_0 I}{2\pi} Ln\left(\frac{D_2}{D_1}\right) = 2I * 10^{-7} Ln\left(\frac{D_2}{D_1}\right)$$

$$\boxed{L_{ext} = 2 * 10^{-7} Ln\left(\frac{D_2}{D_1}\right)}$$

Subject:......................

$L_{total} = L_{int} + L_{ext}$

Inductance of Single phase two wire line :-



1^{st} Conductor

$L_{ext} = 2\times10^{-7}\ Ln\left(\frac{D}{r_1}\right)$

$L_1 = \frac{1}{2}\times10^{-7} + 2\times10^{-7}\ Ln\left(\frac{D}{r_1}\right)$

$L_1 = 2\times10^{-7}\left[\frac{1}{4} + Ln\left(\frac{D}{r_1}\right)\right]$

$L_1 = 2\times10^{-7}\left[\ln e^{1/4} + Ln\left(\frac{D}{r_1}\right)\right]$ $[H/m]$

$L_1 = 2\times10^{-7}\left[Ln\left(\frac{De^{1/4}}{r_1}\right)\right]$

$L_1 = 2\times10^{-7}\left[Ln\left(\frac{D}{e^{-1/4}r_1}\right)\right]$

Conductor 1 $L_1 = 2\times10^{-7} Ln\left(\frac{D}{r_1'}\right)$; $r_1' = e^{-1/4}r_1 = 0.7788\, r_1$

$r_1' \equiv GMR \equiv D_s$

Geometric mean radius

2^{nd} Conductor

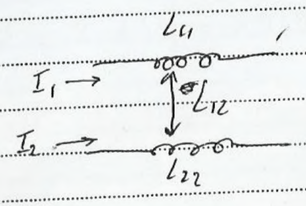
conductor 2 $L_2 = 2\times10^{-7}\ Ln\left(\frac{D}{r_2'}\right)$; $r_2' = e^{-1/4}\, r_2$

Total r for Single phase:

Single phase $L_t = L_1 + L_2$ $[H/m]$

$L = 2\times10^{-7}\ Ln\left(\frac{D}{r_1'}\right) = 2\times10^{-7}\ Ln\left(\frac{1}{r'}\right) + 2\times10^{-7}\ Ln(D)$

Flux linkage in terms of self and mutual inductances:



$\lambda_1 = L_{11} I_1 + L_{12} I_2$ Mutual inductance

Self inductance $\lambda_2 = L_{22} I_2 + L_{12} I_1$

$I_2 = -I_1$

$\lambda_1 = (L_{11} - L_{12})\, I_1$

$\lambda_2 = (L_{22} - L_{12})\, I_2$

A Single phase T.L 35 Km long Consists of two Solid round Conductors each having diameter of 0.9 cm the conductor Spacing is 2.5 m Calculate The inductance per conductor and the total conductane of the Single phase line

Solution

$r' = 0.45 * 0.7788 * 10^{-2} = 3.5046 * 10^{-3}$ m

$L = 2 * 10^{-7} \ln\left(\frac{2.5}{3.5046 * 10^{-3}}\right) = 1.3139 * 10^{-6}$ H/m

$L = 10^{-6} * 1.3139 * 35000 = 0.0459$ H $= 45.9$ mH

$L_{total} = 2L = 0.0919$ H $= 91.9$ mH

For single phase $L_1 = 2 * 10^{-7} \ln\left[\frac{D}{r'}\right]$

$L_{11} = 2 \times 10^{-7} \ln\left(\frac{1}{r_1'}\right)$

$L_{22} = 2 \times 10^{-7} \ln\left(\frac{1}{r_2'}\right)$

$L_{21} = L_{12} = -2 \times 10^{-7} \ln(D)$

General $\lambda_i = L_{ii} I_i + \sum_{J=1}^{n} L_{iJ} I_J \quad ; i \neq J$ [Wb/m]

$\lambda_a = L_{aa} I_a + L_{ab} I_b + L_{ac} I_c$

$\lambda_b = L_{bb} I_b + L_{ba} I_a + I_{bc} I_c$

Similary :

$L = L_{int} + L_{ext} = 2 \times 10^{-7} \ln\left(\frac{D}{r'}\right) = 2 \times 10^{-7} \ln\left(\frac{1}{r'}\right) + 2 \times 10^{-7} \ln$

$L_{int} = \frac{1}{2} \times 10^{-7}$

$L_{ext} = 2 \times 10^{-7} \ln\left(\frac{D}{r}\right)$

Subject:........................ / / ٩

$$\lambda_i = L_{ii} I_i + \sum_{J=1}^{n} L_{iJ} I_J \qquad i \neq J$$

$$\lambda_i = 2\times10^{-7}\left[I_i \ln\frac{1}{r_i} + \sum_{J=1}^{n} I_J \ln\frac{1}{D_{iJ}} \right] \qquad i \neq J$$

$$\lambda_1 = \lambda_{11} + \lambda_{12}$$

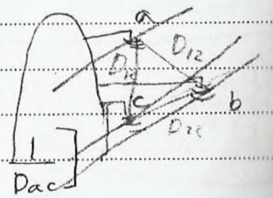
$$= L_{11} I_1 + L_{12} I_2 + L_{13} I_3$$

$$= \left(2\times10^{-7}\ln\frac{1}{r_1}\right) I_1 + \left(2\times10^{-7}\ln\left(\frac{1}{D_{12}}\right)\right) I_2 + \left(2\times10^{-7}\ln\left(\frac{1}{D_{13}}\right)\right) I_3$$

Inductance of Three phase T.L :

1) Symmetrical Spacing المسافات متساوية

("Balancing System") $I_a + I_b + I_c = 0$



$$D_{12} = D_{13} = D_{23} = D$$

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\frac{1}{r_a} + I_b \ln\frac{1}{D_{ab}} + I_c \ln\frac{1}{D_{ac}} \right]$$

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\left(\frac{1}{r_a}\right) + I_b \ln\left(\frac{1}{D}\right) + I_c \ln\left(\frac{1}{D}\right) \right]$$

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\left(\frac{1}{r_a}\right) - I_a \ln\left(\frac{1}{D}\right) \right]$$

$$\boxed{\lambda_a = 2\times10^{-7} I_a \left[\ln\left(\frac{D}{r_a}\right) \right]}$$

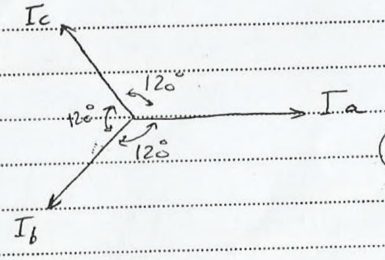
$$L_a = \frac{\lambda_a}{I_a} = 2\times10^{-7} \ln\left(\frac{D}{r}\right)$$

$$L_a = L_b = L_c =$$

2) ASymmetrical Spacing :

$$D_{12} \neq D_{13} \neq D_{23} \neq D$$

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\frac{1}{r_a} + I_b \ln\left(\frac{1}{D_{12}}\right) + I_c \ln\left(\frac{1}{D_{13}}\right) \right]$$



$$a = 1\angle 120$$
$$a^2 = 1\angle 240$$
$$a + a^2 + 1 = 0$$

$$I_b = a^2 I_a$$

$$I_b = I_a \angle 240$$

$$I_c = a I_a = I_a \angle 120$$

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\left(\frac{1}{r}\right) + a^2 I_a \ln\left(\frac{1}{D_{ab}}\right) + a I_a \ln\left(\frac{1}{D_{ac}}\right) \right]$$

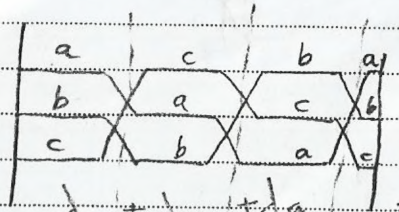
$$\lambda_a = 2\times10^{-7} I_a \left[\ln\left(\frac{1}{r}\right) + a^2 \ln\left(\frac{1}{D_{ab}}\right) + a \ln\left(\frac{1}{D_{ac}}\right) \right]$$

$I_a = a I_b$

Subject: $I_c = a^2 I_b$ $\quad I_a = \frac{I_b}{a^2}$, $I_c = \frac{I_b}{a}$ / / 10

(Trans)pose line

$L_a \times L_b \times L_c$
$> 100 \text{ Km}$



$\lambda_a + \lambda_a + \lambda_a = \lambda_a$

$\lambda_b + \lambda_b + \lambda_b = \lambda_b$

$\lambda_c + \lambda_c + \lambda_c = \lambda_c$

تساويات

$$L_{avg} = \frac{L_a + L_b + L_c}{3}$$

$$L_{avg} = \frac{2\times10^{-7}}{3}\left[3\ln\left(\frac{1}{r}\right) + \ln\left(\frac{1}{D_{12}}\right)(a+a^2) + \ln\left(\frac{1}{D_{13}}\right)(a+a^2)\right.$$
$$\left. + \ln\left(\frac{1}{D_{23}}\right)(a+a^2)\right]$$

$$\boxed{L_{avg} = 2\times10^{-7}\ln\left(\frac{GMD}{r}\right) \quad ; GMD \rightarrow \sqrt[3]{D_{12}D_{23}D_{13}}}$$

$$\boxed{L_a = \frac{\lambda_a}{I_a} = 2\times10^{-7}\left[\ln\left(\frac{1}{r}\right) + a^2\ln\left(\frac{1}{D_{ab}}\right) + a\ln\left(\frac{1}{D_{ac}}\right)\right]}$$

$\lambda_a \times \lambda_b \times \lambda_c$

$L_a \times L_b \times L_c$

$$\lambda_b = 2\times10^{-7}\left[I_b\ln\left(\frac{1}{r}\right) + I_a\ln\left(\frac{1}{D_{ba}}\right) + I_c\ln\left(\frac{1}{D_{bc}}\right)\right]$$

$$\boxed{L_b = \frac{\lambda_b}{I_b} = 2\times10^{-7}\left[\ln\left(\frac{1}{r}\right) + a\ln\left(\frac{1}{D_{ba}}\right) + a^2\ln\left(\frac{1}{D_{bc}}\right)\right]}$$

$\lambda_c =$

$$\boxed{L_c = 2\times10^{-7}\left[\ln\left(\frac{1}{r}\right) + a^2\ln\left(\frac{1}{D_{cba}}\right) + a\ln\left(\frac{1}{D_{cb}}\right)\right]}$$

$I_b = a^2 I_a \qquad a^2 + a + 1 = 0$

$I_b = I_a \angle 240$

i = a

$$\lambda_{a(I)} = 2\times10^{-7}\left[I_a \ln\frac{1}{r} + I_b \ln\frac{1}{D_{12}} + I_c \ln\frac{1}{D_{13}}\right]$$

2 $i = a$

$$\lambda_{a(II)} = 2\times10^{-7}\left[I_a \ln\frac{1}{r} + I_c \ln\frac{1}{D_{13}} + I_b \ln\frac{1}{D_{23}}\right]$$

3 $i = 2$

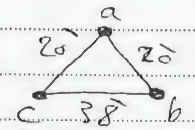
$$\lambda_{a(III)} = 2\times10^{-7}\left[I_a \ln\frac{1}{r} + I_b \ln\frac{1}{D_{13}} + I_c \ln\frac{1}{D_{23}}\right]$$

$$\lambda_{a(avg)} = \frac{\lambda_{a(I)} + \lambda_{a(II)} + \lambda_{a(III)}}{3}$$

$$\boxed{\begin{aligned} \lambda_a &= 2\times10^{-7}\, I_a \ln\frac{GMD}{r} \\ GMD &= \sqrt[3]{D_{12}\,D_{12}\,D_{23}} \\ L_a &= \frac{\lambda_a}{I_a} = 2\times10^{-7} \ln\frac{GMD}{GMr} \end{aligned}}$$

Ex:

A Single circuit, Three phase transposed line operated at 60Hz is arranged as Shown.
The conductors are ACSR Drake, Find The inductive reactance per mile per phase



Subject:....................... / / 11

Similary :

$$L = 2\times10^{-7} \ln\left(\frac{GMD}{GMR}\right)$$

$GMD \rightarrow D \rightarrow$ Single Phase

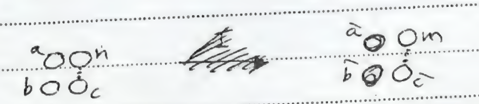
$GMD \rightarrow D \rightarrow$ three Phase Symmetrical

$GMD \rightarrow \sqrt[3]{D_{12}\,D_{13}\,D_{23}} \rightarrow$ three Phase

$GMR = r \rightarrow$ for all

مجموعة / خليط

Inductance of Composite Conductor lines :



Conductor X   Conductor Y

$\uparrow I$ $\downarrow I$

L_x L_y

$$\boxed{L_x = 2\times10^{-7} Ln\left(\frac{D_m}{D_{sx}}\right)}$$ → mutual Geomtric Mean Distance

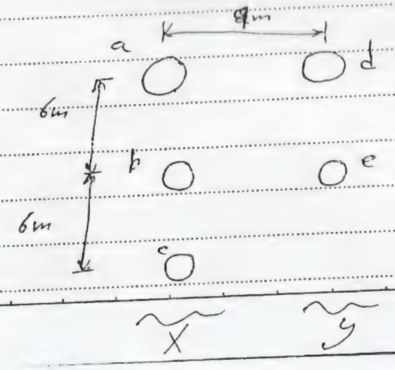
$$\boxed{L_y = 2\times10^{-7} Ln\left(\frac{D_m}{D_{sy}}\right)}$$

Example:

One circuit of a Single phase T.L is composed of Three Solid 0.25cm radius Wires, The return circuit is composed of two 0.5cm radius wires. Find The inductance due to each current in each Side of the Line & The inductance of The complete line in henery per meter & in mH/mi

Note

bandle



Subject:......................

' → feet
'' → inch

Solution

$$X_L = WL$$

$$L = 2\times10^{-7} Ln\left(\frac{GMD}{GMR}\right)$$

$$GMD = \sqrt[3]{(20)(20)(38)} = 24.8 \text{ ft}$$

$$GMR = r' = D_s = 0.0373 \text{ ft}$$

$$L = 2\times10^{-7} Ln\left(\frac{24.8}{0.0373}\right) = 13 * 10^{-7} \text{ H/m}$$

$$X_L = 2\pi(60) * 13 * 10^{-7} = 4.9 * 10^{-4} \ \Omega/m$$

$$\boxed{1 mile = 1609 \text{ m}}$$

$$X_L = 4.9 * 10^{-4} * 1609 = 0.788 \ \Omega/mi$$

Sadat Part 4.8 / /

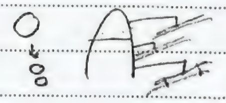
$D_{sy} = \sqrt[2\times2]{D_{dd} * D_{de} * D_{ee} * D_{ed}} = 0.153\,m$

$L_y = 2\times10^{-7}\,Ln\left(\frac{10.743}{0.153}\right) = 8.503\times10^{-7}\ H/m$

$L_{tot} = L_x + L_y = 14.715 * 10^{-7}\ H/m$

$L_{tot} = \frac{14.715 * 10^{-7} * 1609}{1000} = 2.37\ mH/mi$

GMR of Bundled conductors :-



يحسّن / أداء

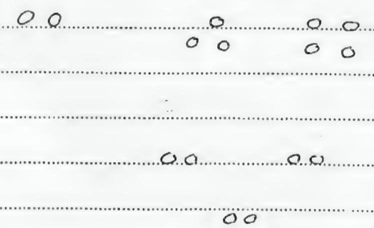
1. Improve the line performance

   سعة

2. Increases power capability of the line

   يقلل

3. Reduces Corona losses



$D_s^b = \sqrt[4]{D_s * d * D_s * d} = \sqrt{D_s d}$

$= \sqrt[9]{D_s^3 d^6} = \sqrt[3]{D_s d^2}$

* لو أعطى r نطلع D_s بالضرب في 0.7788

* كانه قيمة تعدل فإنه D_s لذلك بدل ما نضعها r'

$D_s = r'$

$r' = r * 0.7788$

Subject:...................... / / 13

Solution

$L_x = 2\times10^{-7}\,Ln\left(\frac{D_m}{D_{sx}}\right)$

$D_m = \sqrt[3\times2]{D_{ad} D_{ae} D_{bd} D_{be} D_{cd} D_{ce}}$

$= 10.743\,m$

$D_{ce} \rightarrow$ 9m, 6m, D_{ce}

$D_{ce} = \sqrt{6^2 + 9^2} =$

$D_{sx} = \sqrt[3\times3]{D_{aa} * D_{ab} * D_{ac} * D_{bb} * D_{ba} * D_{bc} * D_{cc} * D_{ca} * D_{cb}}$

$D_s = GMR = r'$

$D_s = 0.25 * 0.7788 * 10^{-2} = 1.94 * 10^{-3}\,m$

$D_{sx} = \sqrt[9]{\quad}$

$D_{sx} = 0.481\,m$

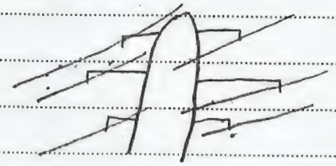
$L_x = 2\times10^{-7}\,Ln\left(\frac{10.743}{0.4815}\right) = 6.212 * 10^{-7}\ H/m$

...nce of Three phase double circuit line:

a o   o c'

b o   o b'

c o   o a'



$L_a = L_b = L_c$

$$GMD = \sqrt[3]{D_{AB} * D_{BC} * D_{AC}}$$

$$D_{AB} = \sqrt[4]{D_{ab} * D_{ab'} * D_{a'b} * D_{a'b'}}$$

$$D_{BC} = \sqrt[4]{D_{bc} * D_{bc'} * D_{b'c} * D_{b'c'}}$$

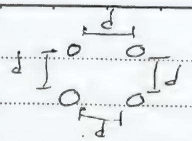
$$D_{AC} = \sqrt[4]{D_{ac} * D_{ac'} * D_{a'c} * D_{a'c'}}$$

$$D_{SA} = \sqrt[4]{D_{aa} * D_{aa'} * D_{a'a} * D_{a'a'}} = \sqrt{D_s D_{aa'}}$$

$$D_{SB} = \sqrt[4]{D_{bb} D_{bb'} D_{b'b} D_{b'b'}} = \sqrt{D_s D_{bb'}}$$

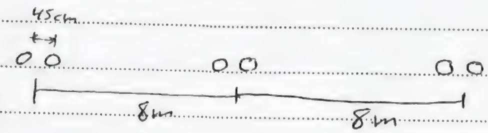
$$D_{SC} = \sqrt[4]{D_{cc} D_{cc'} D_{c'c} D_{c'c'}} = \sqrt{D_s D_{cc'}}$$

$$GMR = \sqrt[3]{D_{SA} * D_{SB} * D_{SC}}$$



$$D_s^d = \sqrt[16]{(D_s \sqrt{2}\, d^3)^4} = 1.09 \sqrt[4]{D_s d^3}$$

Ex:



ACSR Pheasant

$X_L = ?$ [Ω/Km]

$$GMD = \sqrt[3]{8 \times 16 \times 8} = 10.0794 \text{ m}$$

~~GMR~~ =

from Table D_s for phase $= 0.0466$ ft $= 0.0142$ m

for bundle $\to D_s^b = \sqrt{D_s d} = \sqrt{(0.0142)(0.45)} = 0.0799$ m

$$L = 2 \times 10^{-7} \ln\left(\frac{GMD}{GMR}\right) = 9.67 \times 10^{-7} \text{ H/m}$$

$$L = 9.67 \times 10^{-4} \text{ H/Km}$$

$$X_L = 2\pi(60)(L) = 0.3647 \ \Omega/\text{Km}$$

GMD ≡ Geometric mean distance /

Capacitance :

The amount of capacitance between Conductors is a function of :

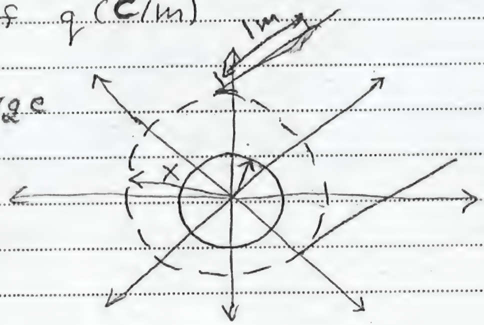
~~Consider a long round Cond. With~~

1. Conductor Size.
2. Spacing between Conductors
3. height above ground

* Consider a long round Conductor with radius r carrying a charge of q (C/m)

flux charge

$\psi = Q$



* The charge on conductor gives rise to an electric field with radial flux lines

* The total electric flux is numerically equals the value of charge on conductor.

GMR ≡ Geometric mean radius

Subject: bundle / /

a oo oo a'
b oo oo b'
c oo oo c'

الفرق في D_s
تحسين D_s^b وتعوض
بيقا

$$\boxed{D_s^b = \sqrt{D_s \times d}}$$

$$D_{SA} = \sqrt{D_s^b D_{aa'}}$$

$$D_{SB} = \sqrt{D_s^b D_{bb'}}$$

واحل المسألة 25
من
Glover

Gauss's Law :

$$D = \frac{q}{A} \qquad C = \frac{Q}{V}$$

electric field density

$$D = \frac{q}{2\pi X (l)} = \frac{q}{2\pi X * 1} = \frac{q}{2\pi X}$$

$$E = \frac{D}{\epsilon}$$

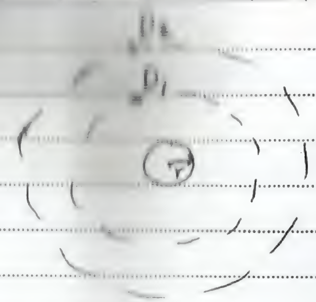
electric field intensity

ϵ → Permettivity $\epsilon_0 \epsilon_r$

$$E = \frac{q}{2\pi X \epsilon_0}$$

The potential difference between Cylinders from position D_1 to D_2 is defind at the work done in moving a unit charge of 1 Coulomb from D_2 to D_1 Through The electric field produced by the charge ~~at ...~~ on conductor

$$V_{12} = \int_{D_1}^{D_2} E \, dx$$



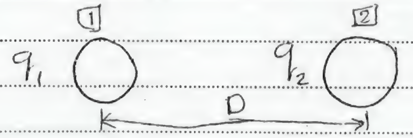
$$\boxed{V_{12} = \int_{D_1}^{D_2} \frac{q}{2\pi \epsilon_0 X} dx = \frac{q}{2\pi \epsilon_0} Ln\left(\frac{D_2}{D_1}\right)} \quad [V/m]$$

$$\boxed{Q = \underset{C/m}{q} * \underset{m}{L} \quad [\text{Colomb}]}$$

Capacitance of a Single phase lines:

Single phase line consisting of 2 Conductors with 1m long

$\boxed{q = q_1 = -q_2}$



* Assuming cond.① is alone

$$V_{12}(q_1) = \frac{q_1}{2\pi \epsilon_0} Ln\left(\frac{D}{r}\right)$$

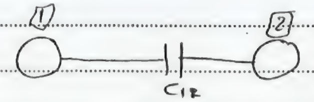
$$V_{1,2} = \frac{q}{2\pi\epsilon_0} \ln\left(\frac{D}{r}\right) - \frac{q}{2\pi\epsilon_0} \ln\left(\frac{r}{D}\right)$$

$$V_{12} = \frac{q}{2\pi\epsilon_0} \left[\ln\left(\frac{D}{r}\right)^2\right] = \frac{q}{\cancel{2}\pi\epsilon} * \cancel{2} \ln\left(\frac{D}{r}\right)$$

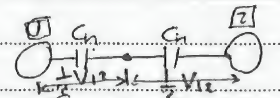
for Single phace

$$\boxed{V_{12} = \frac{q}{\pi\epsilon_0} \ln\left(\frac{D}{r}\right)} \quad [V/m]$$

$$\boxed{C_{1,2} = \frac{q}{V_{12}} = \frac{\pi\epsilon_0}{\ln\left(\frac{D}{r}\right)} \quad [f/m]}$$



* $C_{12} \rightarrow$ Line to Line Capacitance



* $C_n \rightarrow$ Capacitane to neutral

$$\boxed{C_n = \frac{2\pi\epsilon_0}{\ln\left(\frac{D}{r}\right)} \quad f/m}$$

$$C_{12} = \frac{C_n^2}{2C_n} = \frac{C_n}{2}$$

$$\boxed{C_n = 2\, C_{12} \quad f/m}$$

$$\boxed{C_n = \frac{0.0556}{\ln\left(\frac{D}{r}\right)} \quad \mu F/Km}$$

* Assuming Cond. ② is alone

$$V_{21(q_2)} = \frac{q_2}{2\pi\epsilon_0} \ln\left(\frac{D}{r}\right)$$

$$\boxed{\therefore \quad V_{12(q_1)} = -V_{21(q_2)}}$$

q_2 بدل $\longrightarrow$ $$\boxed{V_{12(q_1)} = \frac{q_2}{2\pi\epsilon_0} \ln\left(\frac{r}{D}\right)}$$

$$\boxed{V_{12} = V_{12(q_1)} + V_{12(q_2)}}$$

$$V_{12} = \frac{q_1}{2\pi\epsilon_0} \ln\left(\frac{D}{r}\right) + \frac{q_2}{2\pi\epsilon_0} \ln\left(\frac{r}{D}\right)$$

$$q_1 = -q_2 = q$$

Potenzial Difference in a multi-Conductor Configuration:

$$\boxed{V_{ij} = \frac{1}{2\pi\epsilon_0} \sum_{k=1}^{n} q_k \ln\left(\frac{D_{kj}}{D_{ki}}\right)}$$

for three phase

$$\boxed{V_{12} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\frac{D_{12}}{D_{11}} + q_b \ln\frac{D_{22}}{D_{21}} + q_c \ln\frac{D_{32}}{D_{31}}\right]}$$

Capacitance of 3-phase trasmission Lines:

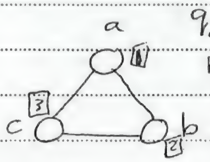
$I_a + I_b + I_c = 0$

$q_a + q_b + q_c = 0$

$r_a = r_b = r_c = r$

$D_{12} = D_{23} = D_{31} = D$

[1] Symmetrical Spacing



$$V_{ab} = \frac{1}{2\pi\epsilon_0} \sum \left[q_a \ln\left(\frac{D_{12}}{D_{11}}\right) \right.$$ $\to D_{11}$

$$\left. + q_b \ln\left(\frac{D_{22}}{D_{12}}\right) + q_c \ln\cancel{\left(\frac{D_{32}}{D_{31}}\right)} \right]$$

$= D_{22}$, $= r$

$\ln(1) = 0$

$$V_{ab} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D}{r}\right) + q_b \ln\left(\frac{r}{D}\right)\right]$$

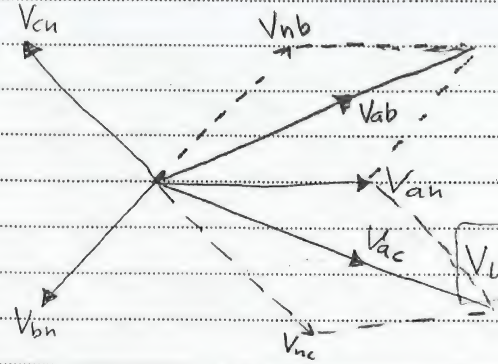
$$\ldots \epsilon_0 \left[q_a \ln\cancel{\left(\frac{D}{D}\right)} + q_b \ln\left(\frac{D}{r}\right) + q_c \ln\left(\frac{r}{D}\right)\right].$$

$$V_{ac} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D}{r}\right) + q_b \ln\cancel{\left(\frac{D}{D}\right)} + q_c \ln\left(\frac{r}{D}\right)\right]$$

$$V_{ab} + V_{bc} = \frac{1}{2\pi\epsilon_0}\left[2q_a \ln\left(\frac{D}{r}\right) - q_a \ln\left(\frac{r}{D}\right)\right]$$

$$\text{''} = \text{''}\left[2q_a \ln\left(\frac{D}{r}\right) + q_a \ln\left(\frac{D}{r}\right)\right]$$

$$\boxed{V_{ab} + V_{bc} = \frac{3}{2\pi\epsilon_0} q_a \ln\left(\frac{D}{r}\right)}$$



$$\boxed{V_{LL} = \sqrt{3}\, V_{Ph} \angle 30^\circ}$$

$$V_{ab} = V_{an} + V_{nb} = \sqrt{3}\, V_{an} \angle 30^\circ = \sqrt{3}\, V_{an}\left[\frac{\sqrt{3}}{2} + j\frac{1}{2}\right]$$

$$V_{ac} = V_{an} + V_{nc} = \sqrt{3}\, V_{an} \angle -30 = \sqrt{3}\, V_{an}\left[\frac{\sqrt{3}}{2} - j\frac{1}{2}\right]$$

$$V_{ab} + V_{ac} = 3V_{an}$$

$V_{ab(avg)} = \dfrac{V_{ab(I)} + V_{ab(II)} + V_{ab(III)}}{3}$

$GMD = \sqrt[3]{D_{12} D_{13} D_{23}}$

$$V_{ab(avg)} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{GMD}{r}\right) + q_b \ln\left(\frac{r}{GMD}\right)\right]$$

Similar

$$V_{ac} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{GMD}{r}\right) + q_c \ln\left(\frac{r}{GMD}\right)\right]$$

$$V_{ab} + V_{ac} = \frac{3 q_a}{2\pi\epsilon_0} \ln\left(\frac{GMD}{r}\right)$$

$$\boxed{C_{an} = \frac{2\pi\epsilon_0}{\ln\left(\frac{GMD}{r}\right)}}$$

Charging Current :

X_L X_C

$\frac{V}{X_c} = I_{ch} = JW\, C_{ab}\, V_{ab}$ for Signale phase line

$I_{ch} = JW\, C_n\, V_{an}$ " 3-phase T.L

V_{an} → phase to neutral voltage

Subject:

19

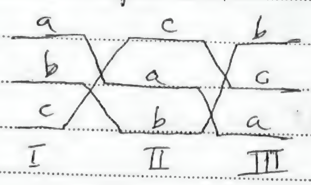
$$3V_{an} = \frac{3 q_a}{2\pi\epsilon_0} \ln\left(\frac{D}{r}\right)$$

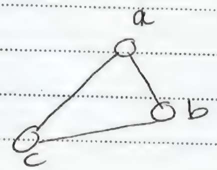
Capacitance to neutral $\boxed{C_{an} = \frac{q_a}{V_{an}} = \frac{2\pi\epsilon_0}{\ln\left(\frac{D}{r}\right)} \quad f/m}$

$$C_{an} = \frac{0.0556}{\ln\left(\frac{D}{r}\right)} \quad \mu f/Km$$

2 Asymmetrical Spacing :

transposition





$$V_{ab_{12}(I)} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D_{12}}{r}\right) + q_b \ln\left(\frac{r}{D_{12}}\right) + q_c \ln\left(\frac{D_{23}}{D_{13}}\right)\right]$$
$C=3$

$$V_{ab_{23}(II)} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D_{23}}{r}\right) + q_b \ln\left(\frac{r}{D_{32}}\right) + q_c \ln\left(\frac{D_{13}}{D_{12}}\right)\right]$$
$C=1$

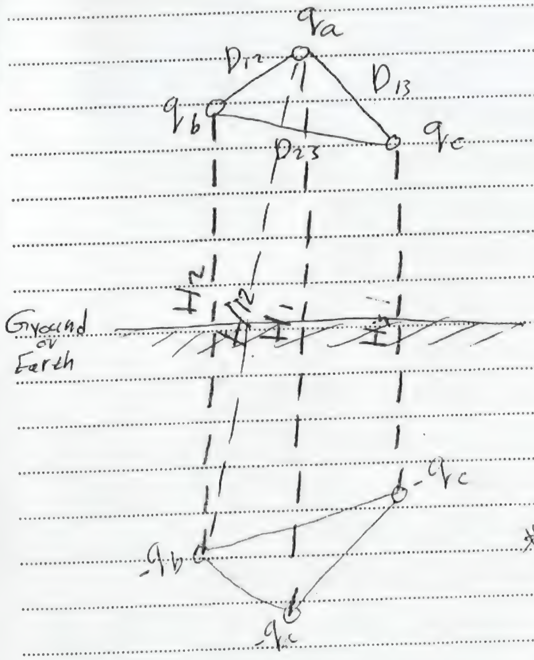
$$V_{ab_{31}(III)} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D_{31}}{r}\right) + q_b \ln\left(\frac{r}{D_{13}}\right) + q_c \ln\left(\frac{D_{21}}{D_{23}}\right)\right]$$
$C=2$

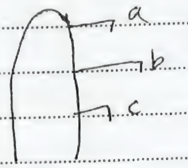
Subject:........

...t of earth on the capacitance of 3ϕ ...L.g =

Assuming That The earth is perfect Conductor in the from of the horizontal plane of infinte extent.

$$V_{ab} = \frac{1}{2\pi\epsilon_0}\left[q_a\left[\ln\left(\frac{D_{12}}{r}\right) - \ln\left(\frac{H_{12}}{H_1}\right)\right] + q_b\left[\ln\left(\frac{r}{D_{12}}\right) - \ln\left(\frac{H_2}{H_{12}}\right)\right] + q_c\left[\ln\left(\frac{D_{23}}{D_{13}}\right) - \ln\left(\frac{H_{23}}{H_{13}}\right)\right]\right]$$





$$\boxed{C_n = \frac{2\pi\epsilon_0}{\ln\left(\frac{GMD}{r}\right) - \ln\left(\frac{\sqrt[3]{H_{12}H_{13}H_{23}}}{\sqrt[3]{H_1H_2H_3}}\right)}}$$

* The effect of earth is to increase the Capacitane of the line.

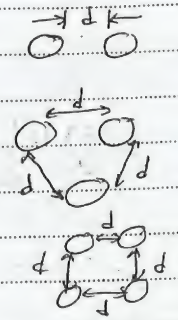
Effects of Bundling:

$$C_n = \frac{2\pi\epsilon_0}{\ln\left(\frac{GMD}{r^b}\right)}$$

$r^b = \sqrt{r*d}$

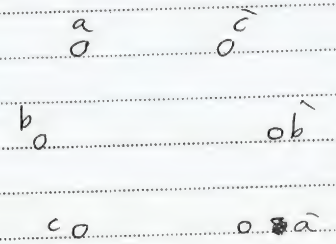
$r^b = \sqrt[3]{r*d^2}$

$r^b = 1.09\sqrt[4]{r*d^3}$



Capacitance of Three phase double circuit lines:

$$C_n = \frac{2\pi\epsilon_0}{\ln\left(\frac{GMD}{GMR_c}\right)}$$



$GMR_c = \sqrt[3]{Z_A * Z_B * Z_C}$

$Z_A = \sqrt{r * D_{aa'}}$

$Z_B = \sqrt{r * D_{bb'}}$

$Z_C = \sqrt{r * D_{cc'}}$

$GMD = \sqrt[3]{D_{AB} * D_{BC} * D_{AC}}$

Similar to inductance

ind the ~~inductance~~ inductive reactance of a Single phase line opearting at 60 Hz. The Cond. is partridge and Spacing is 20 ft.

Solution

for conductor $L = 2*10^{-7} \ln\left(\frac{GMD}{GMR}\right) = 2*10^{-7} \ln\left(\frac{20}{0.0217}\right)$

$L = 1.36 * 10^{-6}$ H/m

for Single phase $L = 2 * L_{\text{for conductor}}$

$L = 2.73 * 10^{-3}$ H/m

$X_L = 1.6553.9$ Ω/mi

Other Way

from A.3 table $X_a = 0.465$ Ω/mi

from table A.4 $X_d = 0.3635$ Ω/mi @ 20

for Conductor $X_L = X_a + X_d = 0.8285$ Ω/mi

for Single phase $X_L = 1.657$ Ω/mi

The use of table in Inductance :-

$X_L = WL = 2\pi f L = 2\pi f * 10^{-7} \ln\left(\frac{GMD}{GMR}\right)$

$X_L = 4\pi f * 10^{-7} \ln\left(\frac{GMD}{GMR}\right)$ Ω/m

$* 1609$

$X_L = 2.022 * 10^{-3} f \ln\left(\frac{GMD}{GMR}\right)$ Ω/mi

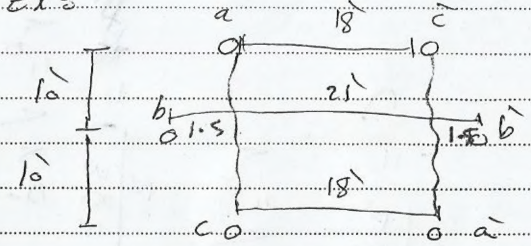
$X_L = \underbrace{2.022*10^{-3} f \ln\left(\frac{1}{GMR}\right)}_{X_a} + \underbrace{2.022*10^{-3} f \ln(GMD)}_{X_d}$

$X_a \triangleq$ Inductive reactane at 1 ft Spacing

$X_d \triangleq$ " " Spacing factor

Subject:.................... / / 22

Exe



$D_{ab} = \sqrt{1.5^2+10^2} = 10.1$ ft

$D_{ab'} = \sqrt{19.5^2+10^2} = 21.9$ ft

$D_{a'b} = 21.9$ ft

$D_{a'b'} = 10.1$ ft

ACSR Ostrich

Find the 60 Hz capacitance ~~susceptance~~ B to neutral per mile per phase

$$C_n = \frac{2\pi\epsilon_0}{\ln\left(\frac{GMD}{r}\right)}$$

$$GMD = \sqrt[3]{D_{AB} D_{BC} D_{AC}}$$

$$D_{AB} = \sqrt[4]{D_{ab} * D_{ab'} * D_{a'b} * D_{a'b'}} = 14.88 \text{ ft}$$

$$D_{BC} = \sqrt[4]{D_{bc} * D_{bc'} * D_{b'c} * D_{b'c'}} = 18.97 \text{ ft}$$

$D_{AC} =$ $\qquad$ $=$

$GMD = 16.1$ ft

.... / /

GMR_c

from table

dia = 0.68 inch

$$GMR_c = \frac{0.68}{2} \text{ inch} = \frac{\square}{12} = 0.0283 \text{ ft}$$

$$r = \sqrt{r_A r_B r_C}$$

$$r_A = \sqrt{GMR_c * D_{aa'}} = 0.8725 \text{ ft}$$

$$r_B = \sqrt{GMR_c * D_{bb'}} = 0.7709 \text{ ft}$$

$$r_C = \sqrt{GMR_c * D_{cc'}} = 0.8725 \text{ ft}$$

$$r = \sqrt[3]{r_A r_B r_C} = 0.837 \text{ ft}$$

$$C_n = \frac{2\pi\epsilon_0}{\ln\left(\frac{16.1}{0.837}\right)} = 18.79 * 10^{-12} \text{ F/m}$$

$$B_c = W C_n = 2\pi f C_n = 7.083 * 10^{-9} \text{ S/m}$$

$$\boxed{B_c = 11.39 * 10^{-6} \text{ S/mi}}$$

E

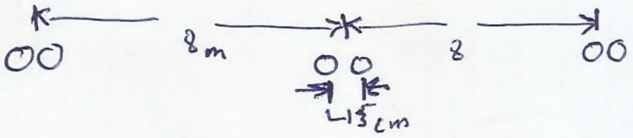
For the bandel cond. Line shown in Fig each is ACSR 1.270.000 cmil Pheasant Find

a → The inductance of the Line in mH/Km/ph and The inductive reactance

b → The series impedance in Ω/mi/ph

c → The Capacitance of the Line in μF/Km/ph and total capacitve reactance at 60 Hz if the Line is 120 Km

D → The charging current per Km if operating Voltage 220 KV



slouzion (a)

Bandel , ACSR,

اولامش عاطى دايمترلو الـ r إذاً من جدول

From the table

$D_s = GMR_o = 0.0466\ Ft$

للبندل الواحد فقط للسنقل كوندكتر

$$L = 2 * 10^{-7} \ln \frac{GMR_x}{GMD}$$

بما أنها ثري فيز

$$GMD = \sqrt[3]{8\ 8\ 16} = 10.08m$$

$$GMR_x = \sqrt{D_s d} \qquad = 0.025$$

$$= \sqrt{0.45\left(\frac{0.0466 * 12 * 2.54}{2.54}\right)} = 0.0799m$$

$$L = 2 * 10^{-7} \ln\left(\frac{10.08}{0.0799}\right) = 0.967 * 10^{-6}\ H/m$$

1

$x_L = wL = 2\pi * 60 * 0.967 * 10^{-6} = \boxed{\checkmark}$ Ω/m

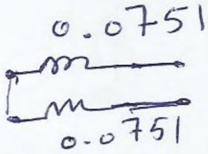
$= \boxed{\checkmark} * 1000 \ \Omega/Km$ $\qquad 0.365 \ \Omega/Km$

b) series impedane . $Z = R + Jx_L$

$x_L = 0.365 \times 1.609 = 0.587 \ \Omega/mi$

بالذهاب الى جدول نطاع R

$R_{20^\circ C} = 0.0751 \ \Omega/mi$



$Z = \frac{0.0751}{2} + 0.587$

if Bandel (3) . $\dots \sqrt[3]{D_s d^2}$ $\qquad \frac{R}{3}$

i Bandel (4) $\ 1.09 \sqrt[4]{D_s d^3}$ $\qquad \frac{R}{4}$

(c)

$C = \frac{2\pi \varepsilon_0}{Lin\left(\frac{GMR}{r^b}\right)}$ $\qquad$ bandel

نطاع r من جدول

$r = \frac{diam}{2}$

$r^b = \sqrt{rd} =$

$r = \frac{1.382}{2}$ inch $= \frac{0.691 * 2.54}{100} = 0.0176m$

$r^b = \sqrt{0.0176 * 0.45} = 0.089$

$C = \frac{2\pi \ 8.85 * 10^{-12}}{Lin\left(\frac{10.08}{0.089}\right)} = 11.75 * 10^{-12} \ F/m$

$x_c = \frac{1}{wc} = \frac{1}{2\pi * 60 * 11.75 * 10^{-12}} = \boxed{\checkmark} \ \Omega/m$ $\quad 225.866 * 10^6$

$\frac{225.866 * 10^6}{120 * 10^3} = 1882$

$x_c = \frac{1}{wC_T} = 1883$

$C_T = 0.01175 \times 120 = 1.409 \mu F$

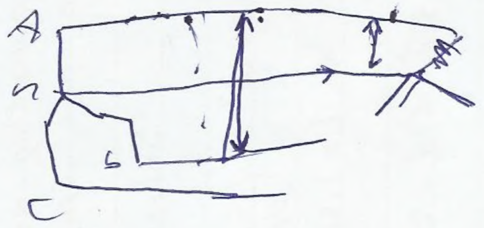
$w = 2\pi F c$

إذا جهد يعطي في المثال Line to Line

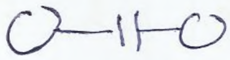
(D) $I_{ch} = j\omega C_n V_{an}$

$= j\,(2*60*11.76*10^{-12})* \frac{220*10^3}{\sqrt{3}} = \square A/m$ $\boxed{0.563\ A/Km}$

وهنا Line to Phase



$\frac{2\pi\varepsilon_0}{\ln(\ )}$



$\frac{\pi\varepsilon_0}{\ln(\ )}$

(E) total reactive Power of the Line

$Q_{3ph} = \sqrt{3}\, V_{LL} I = \sqrt{3}\ 220*10^3 * 0.563 =$

if onephase $Q_{1\phi} = V_{ph} I$